Investigation of Inducer Steady and Unsteady Blade Loads

Stephen W. Gaddis/ED34
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During the development of the alternate turbopump development liquid-oxygen turbopump, scientists questioned the unsteady hydrodynamic blade load used to determine the inducer blade high-cycle fatigue life. Consequently, a full-scale water-flow inducer test article (fig. 88) was used to investigate inducer steady and unsteady blade loads. Conducted in MSFC's Inducer Test Loop, tests were performed at reduced shaft speeds and ambient water temperature, and were successfully completed in March 1995. The four-bladed, unshrouded, 14.6-degree inducer was tested at scaled water-flow conditions simulating the design-flow coefficient and a range of suction-specific speeds from 5,000 to 16,000 (head falloff). Steady and unsteady measurements—inducer pressure rise, unsteady shroud pressure, and steady and unsteady blade strains—were recorded in both stationary and rotating reference frames. Four strain gauges were mounted per blade. Each was spaced equally chordwise along the blade, approximately 33 percent radially from the inducer hub. Testing was conducted at design conditions to measure steady and cavitation-generated unsteady blade loads to verify the inducer blade high-cycle fatigue life.

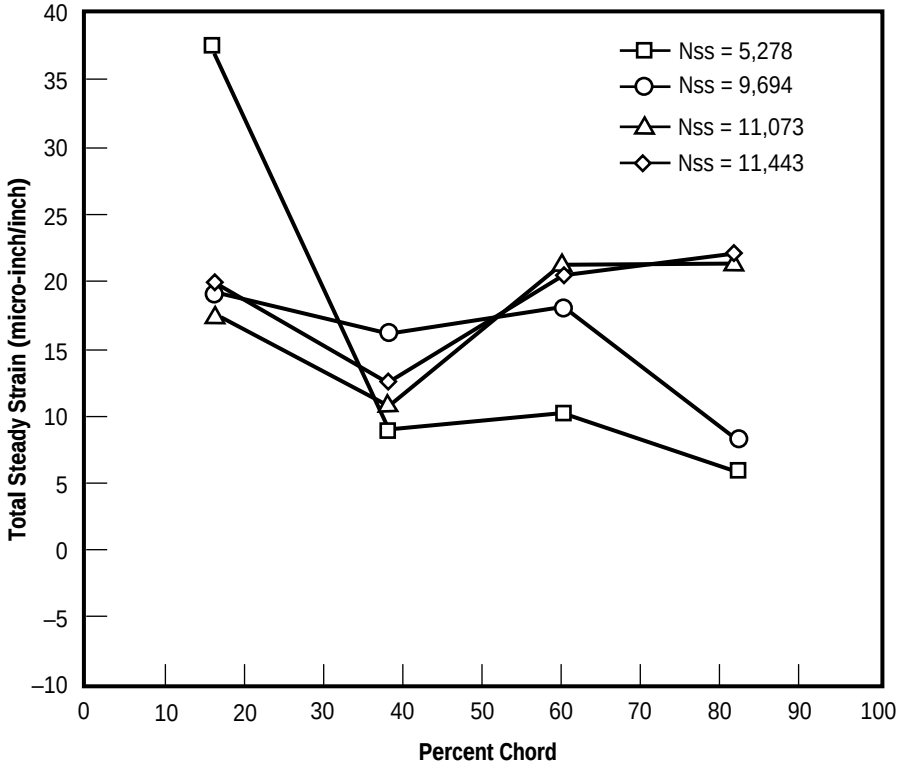

FIGURE 88.—Steady-state hydrodynamic microstrain for blade 1 only versus blade chord for different suction-specific speeds (Test #ITL0006, 14.6-degree inducer, 30-mil-tip clearance, 100-percent Q/N, running 36/0, 37/0, 38/1, 39/0).

Steady strains for blades 1 and 3 (fig. 88) indicated: (1) higher steady strain at the blade leading edge and trailing edge; and (2) at higher suction-specific speeds, the blade chordwise strains tended to be more evenly distributed. At different suction-specific speeds, three inducer cavitation modes were observed: blade-tip vortex, blade alternating, and asymmetric. These cavitation modes changed the inducer unsteady blade loads depending upon the particular mode experienced. At the 38-percent chord position, the blade unsteady strains for all four blades (fig. 89) indicated the change in unsteady strain as the cavitation modes varied with increasing suction-specific speed.

Testing concluded that a maximum strain ratio of unsteady to steady blade hydrodynamic strains to be 14 percent, which confirmed adequate inducer life for the alternate turbopump develop-

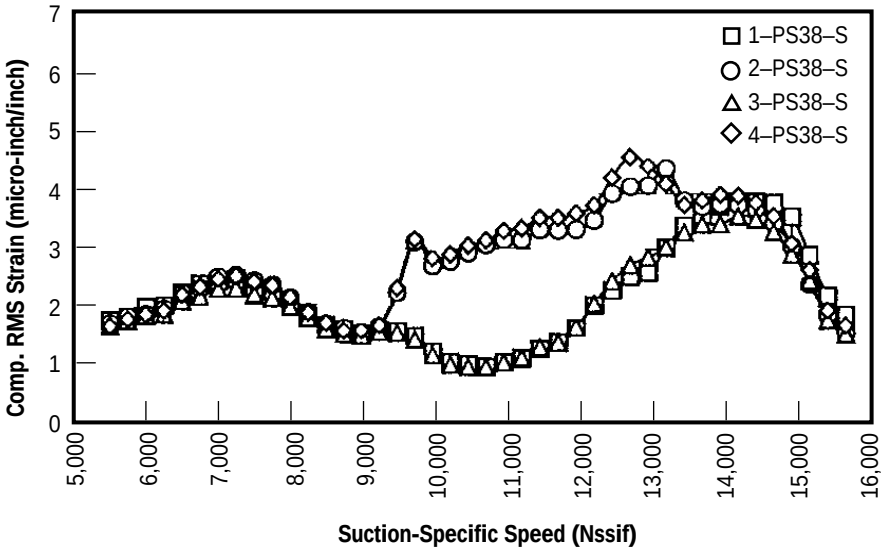

FIGURE 89.—MSFC inducer blade strain test (ITL0006) (run 40/1, 14.6 degrees, 0.030-inch tip cir., 4,200 revolutions per minute, composite RMS unsteady blade strain).

ment high-pressure liquid-oxygen pump program. Testing also upheld the conservative design practice of using a strain ratio of 20 to 30 percent to account for unsteady hydrodynamic loads.

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